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Calcium Solubilization Ability and Anti-Inflammatory Effects of Hydrolyzed Casein

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Abstract This study performed to evaluate the applicability of functional dairy food materials by comparing the calcium solubilization ability and anti-inflammatory effects of hydrolyzed casein protein. Commercial enzyme (Alcalase[®]; Neutrase[®]; Protamex[®]; Flavourzyme[®]) was added to the 10% casein solution to prepare the casein hydrolysates. Samples obtained every hour [1:200 (w/v)]. According to results of measuring the degree of hydrolysis (DH), all of four enzymatic hydrolysates increased rapidly from 30 to 40 min, and after 150 min, there were no change. Protamex[®] and Neutrase[®] had the highest DH compared to others enzymatic hydrolysates. After that, peptides obtained throughout a preparative liquid chromatography system. In the calcium solubility experiments, neutrase fraction (NF) 4 and NF7 showed similar activities with casein phosphopeptide (CPP). *In vitro* cell experiments showed that no cytotoxicity except for NF6. Also, the production of nitric oxide (NO) inhibited as the concentration of fraction samples increased. The cytokine (IL-1 α , IL-6, and TNF- α) production was lower than lipopolysaccharide (+) group significantly. Therefore, the possibility of anti-inflammatory activity found in the hydrolyzed samples. According to the above experiments, NF3 and Protamex Fraction (PF) 3 selected. Amino acids selected throughout an AccQ-Tag system. As a result, 17 species of amino acids and several species of unknown amino acids identified. Both fractions had the highest content of phenylalanine. This study identified the potential of biologically active and functional peptides derived from casein that affect the food and dairy industry.

Keywords milk protein, casein, calcium solubilization ability, anti-inflammatory effects, amino acids

Introduction

Milk is made of milk fats, proteins, carbohydrates, water-soluble vitamins, minerals, and water. The whey protein and a casein exists as protein components. Casein is major component of milk proteins and it is widely studied because it has high availability and nutritional importance. It is about 3% in milk and it is about 80% of all protein in milk. Also, casein protein consisted of beta-casein fragments and molecular weight is about 75,000–375,000 kDa (Chio et al., 2011).

In recent years, calcium intake has increased, but its utilization in the body is low, leading to various deficiency diseases. Lack of calcium is the cause of various diseases such as poor bone growth, fracture, osteoporosis, hypercholesterolemia, arteriosclerosis, hypertension, and hyperlipidemia (Raisz and Smith, 1989; Zhao et al., 2005). In order to increase calcium intake, the use of calcium in the body should be higher than that of eating large amounts (Greger, 1988).

It has been reported that casein itself affects calcium absorption (Bronner, 1987), affecting immune system, so, it affects final immune response and cellular function (Coste and Tome, 1991; Kayser and Meisel, 1996).

Casein protein is characterized with a type of amino acid constituents. The use of casein hydrolysates that retain the bioactive amino acid domain or sequence may be a better alternative to prevent rancidity in foods without affecting food quality (Díaz and Decker, 2004). Also, the enzymatic hydrolysis of casein may act in a body as regulatory components with a hormone activity which can modulate specific physiological functions (Meisel and FitzGerald, 2003).

In vitro and *in vivo* enzymatic proteolysis of casein proteins produce bioactive peptides (Jelen and Lutz, 1998), which have specific biological functions throughout their ability to affect cellular function (Meisel, 1997). Because casein phosphopeptide (CPP) have a potential effects to deliver calcium as a functional ingredient (Kitts and Yuan, 1992). It is important to examine their immunological activity further. In response to this, 32 articles examining the role of hydrolyzed infant formulas in the prevention of allergies have been investigated (Hays, 2006).

Through this, if casein is hydrolyzed using proteolytic enzyme to develop a specific peptide similar with CPP, superior calcium absorption and anti-inflammatory effects will be expected.

In addition, researchers at the Department of Pediatric Gastrointestinal and Nutrition at Johns Hopkins of Medicine reported that infants fed with totally hydrolyzed casein and infants had a reduced incidence of atopic disease during the five years of life. Also, casein hydrolysates have been reported that it has a biological function on cellular function (Meisel, 1997), and it affects immune system cells (Coste and Tome, 1991; Kayser and Meisel, 1996).

Analysis of bioactive peptides has been made in several studies. These peptide sequences, encrypted within proteins, are liberated *in vivo* during gastrointestinal digestion or *in vitro* by fermentation with proteolytic starter cultures or using proteases. BAP generally comprises 2–20 amino acid residues (Poosapati et al., 2018).

In this regard, the objective of this study is development of a specific peptide which have a similar effect with CPP and researching a peptide which has excellent physiological properties and promotes calcium absorption.

Materials and Methods

Preparation of casein hydrolysates

Commercial casein (95% protein) obtained from Meggle food Ingredients (Wasserburg, Germany).

A 10% casein solution prepared by mixing 10% casein and 90% 0.1 M potassium phosphate buffer (pH 7.4). After a sterilization for 10 min at 90°C, a pH is adjusted to 7.0 which is optimum active pH of the enzyme with 1 N NaOH (Sigma, St. Louise, MO, USA).

Commercial enzymes used with Alcalase® 2.4 L FG (Protease from *Bacillus licheniformis*, 5 U/g), Neutrase® 0.8 L (Protease from *Bacillus amyloliquefaciens*, 0.8 U/g), Protamex® (Protease from *Bacillus* sp., 1.5 U/g) and Flavourzyme® (Protease from *Aspergillus oryzae*, 500 U/g). All commercial enzymes purchased from Novozymes™ (Bagsvaerd, Denmark).

The enzymes added at a ratio of 1:200 (w/v) based on the substrate, and shaken at 120 rpm in a shaking water bath at 50°C. The samples taken at 30 min and inactivate the enzymes at 90°C for 10 min. It preceded to 240 min. After a cooling at 20°C,

the supernatant collected by centrifugation for 20 min under conditions of 4,000×g and 4°C. The supernatant was filtered with PVDF 0.22 Syringe membrane filter (Futecs, Daejeon, Korea). Samples stored at -20°C and used for each experiment.

Degree of hydrolysis (DH) of casein hydrolysates

The hydrolysis degree of casein hydrolysates measured using the Lowry method (Lowry, 1951). The Lowry solution A and B prepared for the degree of hydrolysis (DH). To prepare solution A, 1% cupric sulfate (Sigma) and 2% Sodium potassium tartrate (Sigma) mixed at a 1:1 ratio (v/v), and 1.0 mL of the mixed solution and 50 mL of 2% Na₂CO₃ (DaeJung Chemical & Metals, Siheung, Korea) were mixed. Solution B used to prepare a 1 N Folin-Ciocalteau reagent (Sigma).

First, 1.0 mL of casein hydrolysates and the same amount of 20% TCA (Duksan Chemical, Ansan, Korea) mixed and maintained for 1 h to precipitate 20% TCA soluble protein. It centrifuged at 11,000×g for 20 min. The supernatant and dissolved residue removed in 5.0 mL of 0.1 N NaOH (Sigma).

Thereafter, 1.0 mL of a casein hydrolysates and 5.0 mL of solution A mixed and reacted at room temperature for 10 min. After that, 0.5 mL of solution B added and the contents mixed immediately with vortex mixer. After reacting for 30 min, an absorbance measured at 600 nm. An equivalent amount of protein calculated from standard curve prepared using bovine serum albumin (Sigma). A bovine serum albumin measured in the range of 20 to 200 µg/mL.

The amount of TCA soluble protein measured and calculated by the following equation.

$$\text{Degree of hydrolysis (\%)} = \frac{\text{Soluble protein from 10\% TCA}}{\text{Total protein}} \times 100$$

Purification of casein hydrolysates

In order to obtain peptide fractions from casein hydrolysates, gel filtration throughout a preparative chromatography system performed (Waters, Milford, MA, USA).

Peptides that identified in SDS-PAGE separated on a preparative scale for further study. The preparative pump (Waters) and preparative liquid chromatography W600 (Waters) used with a Dual λ Absorbance detector W2487 (Waters) and W717 Autosampler (Waters).

The casein hydrolysates dissolved in 5 mM sodium phosphate buffer with 0.15 M NaCl (Sigma), pH 7.0. It filtered with a PVDF 0.45 µm sterile syringe membrane filter (Futecs). After that, casein hydrolysates is loaded 3.0 mL throughout a Hiprep 16/60 Sephacryl S-100 HR column (GE Healthcare Life Sciences, Marlborough, MA, USA) and eluted at flow rate of 1.0 mL/min. A detector was set at 280 nm.

All fractions obtained throughout a gel filtration with Hiprep 16/60 Sephacryl S-100 HR column on preparative chromatography system collected and fractions stored at -20°C (Table 1).

Calcium solubilization ability

In the experiment of promoting calcium absorption, the method of Naito (1986) and Yamamoto et al. (1994) was slightly modified to measure the effect on precipitation in solution after calcium phosphate formation.

The 10 mM calcium chloride (Sigma) and 20 mM sodium phosphate buffer were prepared. After that, 0.5 mL of 10 mM calcium chloride and 0.5 mL of casein hydrolysate fraction samples mixed. And a 1.0 mL of 20 mM sodium phosphate buffer added. The mixed solution incubated at 37°C for 2 h and centrifuged at 2,000×g for 30 min at 25°C.

Table 1. Condition of preparative liquid chromatography system

Instrument	Condition
Column	Hiprep 16/60 Sephacryl S-100 HR column (GE Healthcare Life Sciences)
Mobile phase	5 mM sodium phosphate buffer (0.15 M NaCl, pH 7.0)
Detector (Detection)	Waters Dual λ Absorbance Detector W2487 (280 nm)
Flow rate	1 mL/min
Injection volume	3 mL

Calcium solubility measured using calcium colorimetric kit (Gene Tex, Pkwy Irvine, CA, USA) for the whole solution and the supernatant collected after centrifugation.

The whole solution and supernatant samples dispensed into each 10 μ L 96 well plate, followed by mixing of chromogenic reagent to 90 μ L and calcium assay buffer to 60 μ L. After reacting for 5 min in dark room at room temperature, an absorbance measured at 570 nm.

Calcium concentration calculated according to the first equation below, and calcium solubility calculated according to the second equation below. All protein concentration of casein hydrolysate fraction samples were 200 μ g/mL.

$$\text{Calcium concentration (mg/mL)} = \frac{Sa}{Sv}$$

*Sa = Sample amount from standard curve

*Sv = Sample volume

$$\text{Calcium solubility (\%)} = \frac{\text{Calcium concentration in supernatant}}{\text{Calcium concentration in whole solution}} \times 100$$

Cytotoxicity of casein hydrolysate fractions (MTT assay)

RAW 264.7 cell is a macrophage cell of mouse. RAW 264.7 cells obtained from the Dankook University (Cheonan, Korea). Cells grown in Dulbecco's Modified Eagle Medium (DMEM) including 10% heat-inactivated fetal bovine serum (FBS). The incubator temperature adjusted to 37°C and maintained at 5% CO₂.

RAW 264.7 cells seeded in 96-well cell culture plates at a density of 5×10⁴ cells/well and incubated for 16–18 h. After removing the medium, RAW 264.7 cells treated with various concentrations of fraction samples for 20–22 h.

After that, 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (Sigma) solution added to each well at a final concentration of 5 mg/mL and incubated (37°C, 5% CO₂). After 2–3 h, culture supernatants removed, and 100 μ L of dimethyl sulfoxide (Sigma) added to each well to completely and dissolve formazan crystals. The absorbance measured at 540 nm (Fotakis and Timbrell, 2006).

Measurements of nitric oxide (NO assay)

RAW 264.7 cells seeded in 96-well cell culture plates at a density of 5×10⁴ cells/well and incubated for 16–18 h. The amount of nitric oxide (NO) calculated by measuring the amount of nitrite, an oxidized product, in the cell culture supernatants as previously explained. After removing the medium, RAW 264.7 cells treated with various concentrations of

fraction samples in medium for 2–3 h.

After that, lipopolysaccharide (LPS) with final concentration of 100 ng/mL treated and stimulated at the same volume in medium for 20–22 h. A Griess reagent added to the supernatant in a ratio of 1:1 (v/v). The absorbance at 540 nm measured in a microplate reader after 15 min at room temperature (Lim, 2010).

Measurement of cytokine (ELISA)

RAW 264.7 cells seeded in 96-well plates at a concentration of 5×10^4 cells/mL for 24 h, preprocessed cell free extracts were prepared. After that, the supernatant taken and the cytokine content measured by a Mouse IL-1 α , IL-6 and Mouse TNF- α ELISA kit (Komabiotech, Seoul, Korea) using an enzyme-linked immunosorbent assay (ELISA).

The 100 μ L of fraction samples added to each well coated with specific antibodies against cytokines (IL-1 α , IL-6, and TNF- α), reacted at room temperature for 2 h. And the supernatant removed and washed five times with washing buffer. Thereafter, detection antibody added to react with antibody. Also, streptavidin-horseradish peroxidase (HRP) conjugated with avidin added and reacted at room temperature for 30 min. After that, it washed for 4 times. A 100 μ L of Tetramethylbenzidine (TMB) added to each well as a substrate. After that, it incubates at the room temperature as a proper color development. A stop solution added to each well and absorbance measured at 450 nm (Phelan et al., 2009).

Profiling of amino acids (AccQ-Tag system)

Amino acid profiling preceded according to Waters amino acid analysis AccQ-Tag manual. A waters AccQ-Tag-Fluor reagent kit used for a derivatization of the sample and standard. An amino acid standard (Sigma) used as a standard. The range of sample amount is 0.02–0.08 μ g (20–1,000 pmol). Others system condition shown in Table 2 which showed in below.

Results

Degree of hydrolysis (DH) of casein hydrolysates

The degree of casein hydrolysis defined as the percentage of total number of peptide bonds in a protein that has been cleaved during hydrolysis (Adler-Nissen, 1986). The DH of the four enzymes tended to increase into a similar pattern. There was no significant difference from 150 min and after increasing from 120 min to 150 min. Among them, the highest DH of the casein hydrolyzed by Protamex[®] measured, and the DH of the casein hydrolyzed by Neutrase[®] and Flavourzyme[®] are similar (Fig. 1).

Table 2. Profiling of amino acids (AccQ-Tag system)

Instrument	Condition
Column	Waters AccQ-Tag (Waters)
Mobile phase	Waters AccQ-Tag eluent A, 60% Acetonitrile (pH 5.02)
Detector (detection)	Waters Dual λ Absorbance Detector W2487 (280 nm)
Flow rate	1 mL/min
Injection volume	10 μ L

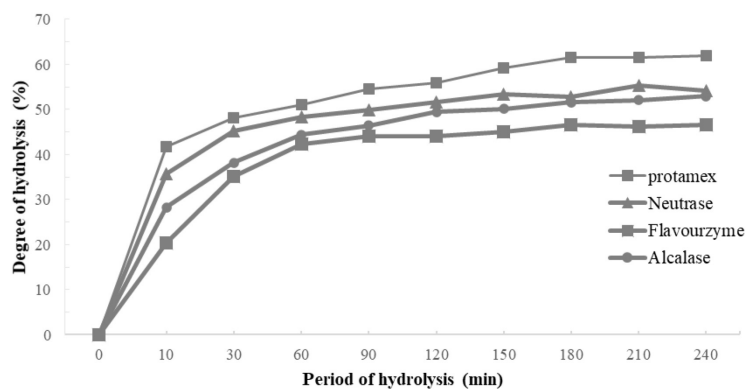


Fig. 1. Degree of hydrolysis (DH) of casein hydrolysates. Reaction were carried out in a water bath (50°C, 120 rpm). All enzymes were applied at concentration 1:200 (w/v) to the casein solution. Alcalase® 2.4 L; Neutrase® 0.8 L; Flavourzyme®; Protamex® (Novozymes™).

Purification of casein hydrolysates

Neutrase® and Protamex® selected throughout the results of DH. Peptide fractions of casein hydrolysates isolated using Hiprep 16/60 Sephacryl S-100 HR column in preparative liquid chromatography system. Each fraction separated by molecular weight. 10 peptide fractions obtained totally. Each fraction compared to the original casein hydrolysates via SDS-PAGE for a molecular weight (Data are not shown) (Figs. 2 and 3).

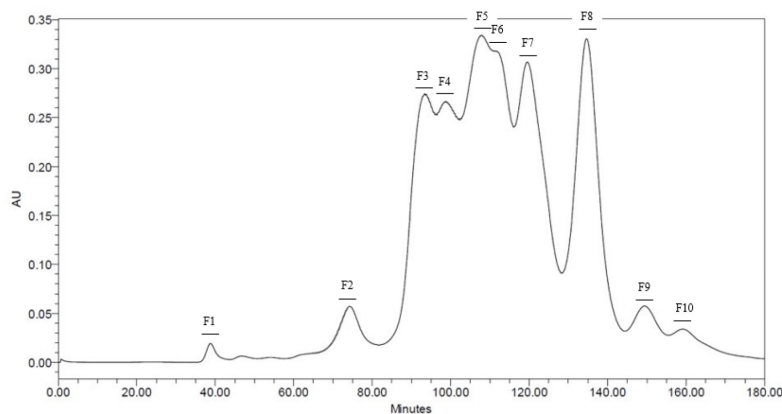


Fig. 2. Separations of casein hydrolysates using Neutrase® in preparative LC system. F#, fraction number in prep LC system.

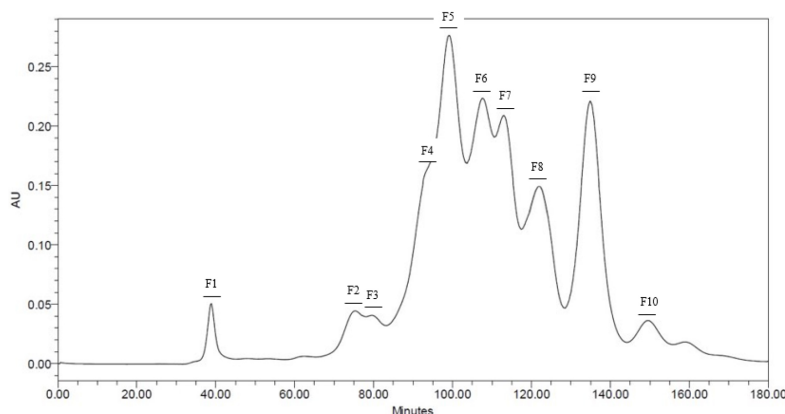


Fig. 3. Separations of casein hydrolysates using Protamex® in preparative LC system. F#, fraction number in prep LC system.

Calcium solubilization ability

CPP contains phosphoserine and solubilizes calcium, which can promote calcium solubilization ability. In this study, calcium solubility measured to determine whether each fraction promote calcium solubilization ability similar with CPP.

According to experimental results, CPP showed high calcium solubility with 93.67%. Phosphoserine contained in CPP solubilizes calcium, resulting in high calcium solubility.

Both Neutrase[®] and Protamex[®] hydrolysate fractions showed lower calcium solubility than CPP. Also, F4 and F7 in the Neutrase[®] fractions showed lower than CPP but about 80% calcium solubility. The F6 have a similar level with 79.84%. The Protamex[®] fractions showed lower calcium solubility than CPP, but F3, F4, F5, F6, and F7 showed calcium solubility of about 80% or more.

This may show the potential of calcium solubilization ability. Based on the results of the above experiments, fractions that showed good activity selected (Figs. 4 and 5).

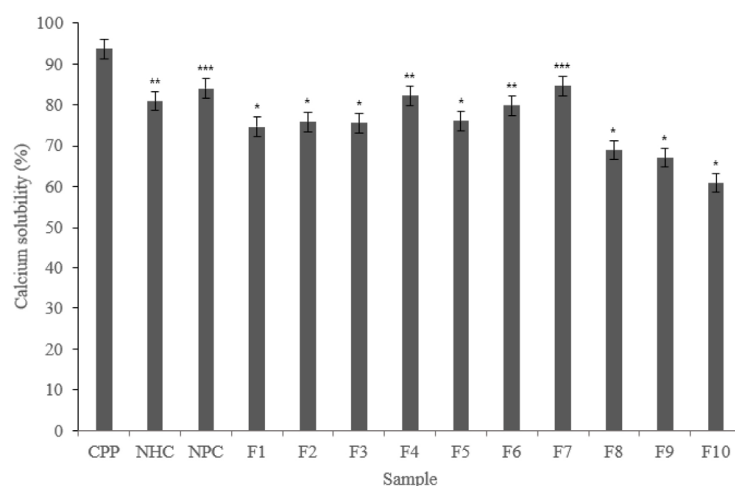


Fig. 4. Calcium solubility of casein hydrolysate fractions using Neutrase[®]. * p<0.05, ** p<0.01, *** p<0.001; CPP vs. sample. CPP, casein phosphopeptide; NHC, non-hydrolyzed casein; NPC, non-purified casein; F#, fraction number in Prep LC system. All samples protein concentration were 200 µg/mL. All values were mean±SD of triplicates.

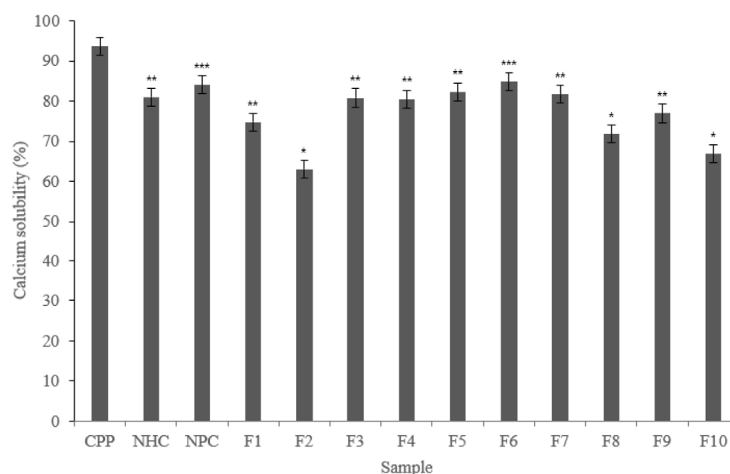


Fig. 5. Calcium solubility of casein hydrolysate fractions using Protamex[®]. All samples protein concentration were 200 µg/mL. All values were mean±SD of triplicates. * p<0.05, ** p<0.01, *** p<0.001; CPP vs. sample. CPP, casein phosphopeptide; NHC, non-hydrolyzed casein; NPC, non-purified casein; F#, fraction number in Prep LC system.

Cytotoxicity of casein hydrolysate fractions

Cytotoxicity test via the MTT assay is used *in vitro* toxicology experiment widely. According to experimental results, despite the increase in concentration, there were no significant differences by concentration. Except for a NF6, there were no significance on concentration differences and cell death. In addition, it showed cell viability of 80% or more.

Therefore, it confirmed that there are no cytotoxicity of fraction samples on macrophage cells (Fig. 6).

Measurement of nitric oxide

The NO effect an important role in a blood coagulation, blood pressure regulation and immune function against cancer cells. However, it oxidized like reactive oxygen species (ROS) and converted into active NO. It produces oxidants that cause cytotoxicity. The NO produced by cells exposed to inflammatory mediators increased in tissue damage or various inflammatory diseases.

According to the results of the study, as the concentration of fraction samples increased, NO production inhibited. The MTT experiments showed that inhibition of NO production not caused by cytotoxicity (Fig. 7).

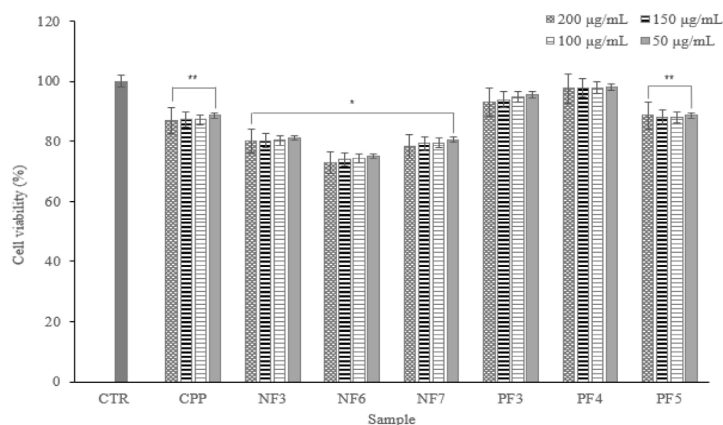


Fig. 6. Effects of hydrolysate fractions on cell viability in RAW 264.7 cells. All values were mean±SD of triplicates. * $p < 0.05$, ** $p < 0.01$; CTR vs. NF# or PF#. CTR, control; CPP, casein phosphopeptide; NF#, Neutrase® hydrolysate fraction number in Prep LC system; PF#, Protamex® hydrolysate fraction number in Prep LC system; 200, 150, 100, 50 µg/mL: Samples protein concentration.

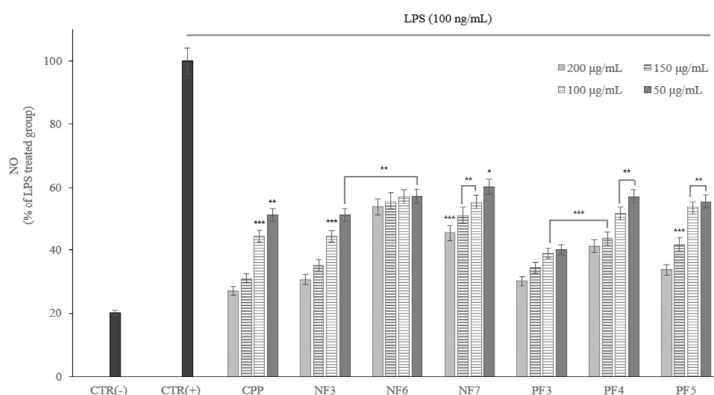


Fig. 7. Effects of hydrolysate fractions on NO in LPS-stimulated RAW 264.7 cell. All values were mean±SD of triplicates. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; CTR (-) vs. NF# or PF#. NO, nitric oxide; LPS, lipopolysaccharide; CTR, control; CPP, casein phosphopeptide; NF#, Neutrase® hydrolysate fraction number in Prep LC system; PF#, Protamex® hydrolysate fraction number in Prep LC system. 200, 150, 100, 50 µg/mL: Samples protein concentration.

Measurement of cytokine

To maintain immune balance, they must be direct or indirect interactions of immune cells. The cytokines can induce proliferation, differentiation, changes in function and activity of various immune cells. A disease is mostly associated with inflammation, and inflammatory cells secrete inflammatory cytokines that induce inflammation (Barland et al., 2004). In this study, the expression levels of IL-1 α , IL-6, and TNF- α measured.

According to the results of cytokine measuring using ELISA, three cytokine (IL-1 α , IL-6, and TNF- α) production was significantly lower than LPS(+) group (* $p < 0.05$). Based on results, the possibility of anti-inflammatory activity found in the hydrolysate fractions. In addition, the low expression level of TNF- α from macrophage effect by samples prevents the activation of proinflammatory cytokines which is produced by the expression of TNF- α . It reduces the inflammatory response (Figs. 8–10).

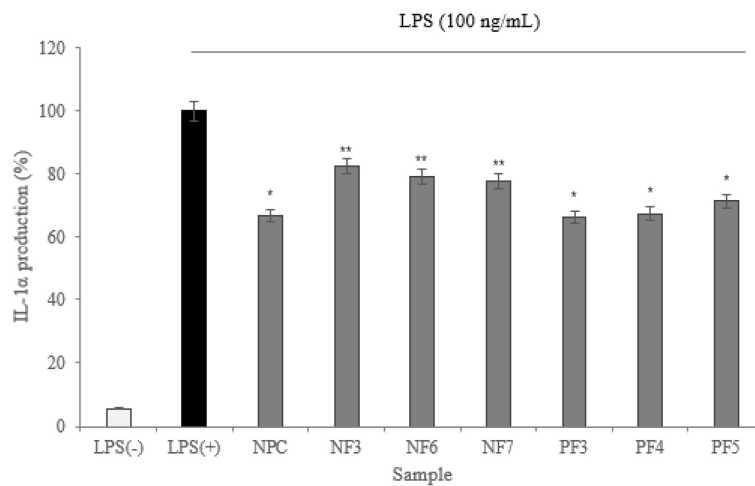


Fig. 8. Comparison of IL-1 α production in LPS-stimulated RAW 264.7 cells. All values were mean \pm SD of triplicates. * $p < 0.05$, ** $p < 0.01$; LPS(+) vs. NF# or PF#. LPS, lipopolysaccharide; NPC, non-purified casein; NF#, Neutrase[®] hydrolysate fraction number in Prep LC system; PF#, Protamex[®] hydrolysate fraction number in Prep LC system.

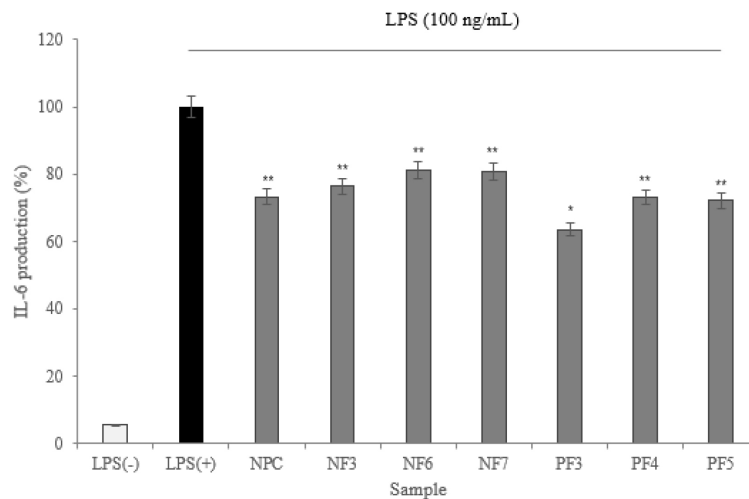


Fig. 9. Comparison of IL-6 production in LPS-stimulated RAW 264.7 cells. All values were mean \pm SD of triplicates. * $p < 0.05$, ** $p < 0.01$; LPS(+) vs. NF# or PF#. LPS, lipopolysaccharide; NPC, non-purified casein; NF#, Neutrase[®] hydrolysate fraction number in Prep LC system; PF#, Protamex[®] hydrolysate fraction number in Prep LC system.

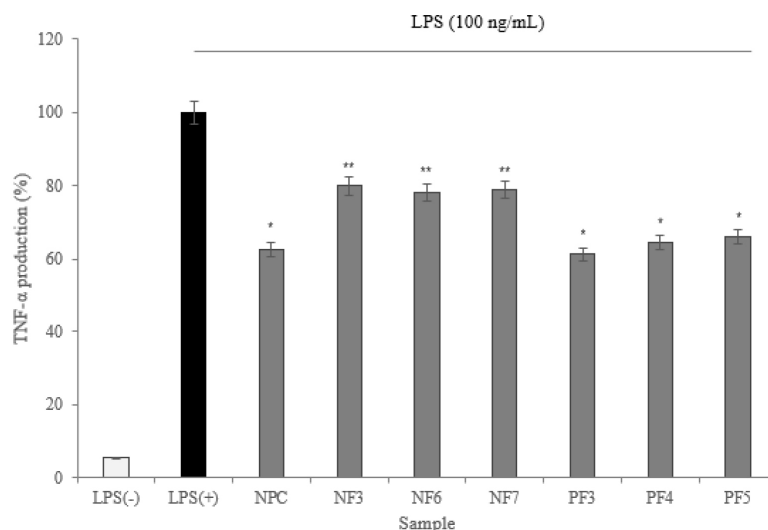


Fig. 10. Comparison of TNF- α production in LPS-stimulated RAW 264.7 cells. All values were mean \pm SD of triplicates. * $p < 0.05$, ** $p < 0.01$; LPS(+) vs. NF# or PF#. LPS, lipopolysaccharide; NPC, non-purified casein; NF#, Neutrase[®] hydrolysate fraction number in Prep LC system; PF#, Protamex[®] hydrolysate fraction number in Prep LC system.

Profiling of amino acids

Based on the above experiment results, NF3 and PF3 selected. According to results of confirming amino acid sequence of the selected fractions throughout the AccQ-Tag system, 17 species of amino acids and several species of unknown amino acids identified (Figs. 11 and 12; Table 3). Both fractions had the highest content of phenylalanine and the lowest content of threonine and arginine.

Discussion

In this study, proteolytic enzymes used to focus on the function of specific peptides derived from the hydrolysis of a casein.

According to results, the DH of the four enzymes tended to increase in a similar pattern. There was no significant difference after increasing from 120 min to 150 min. DH of Protamex[®] found to increase most appropriately. All

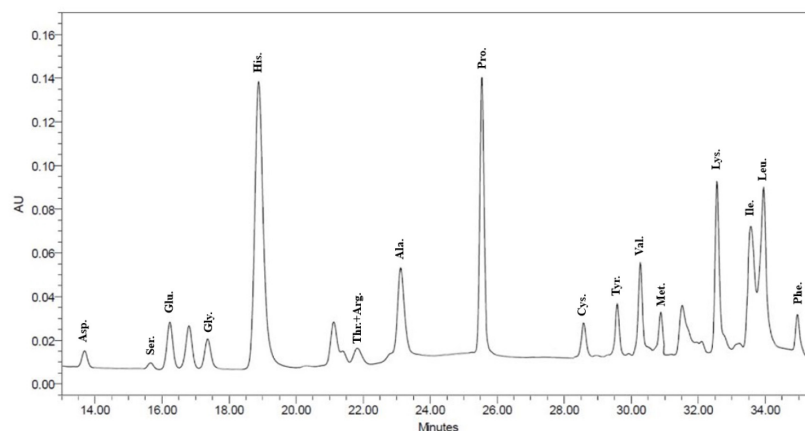


Fig. 11. HPLC chromatogram of amino acids in selected Neutrase[®] hydrolysate fraction.

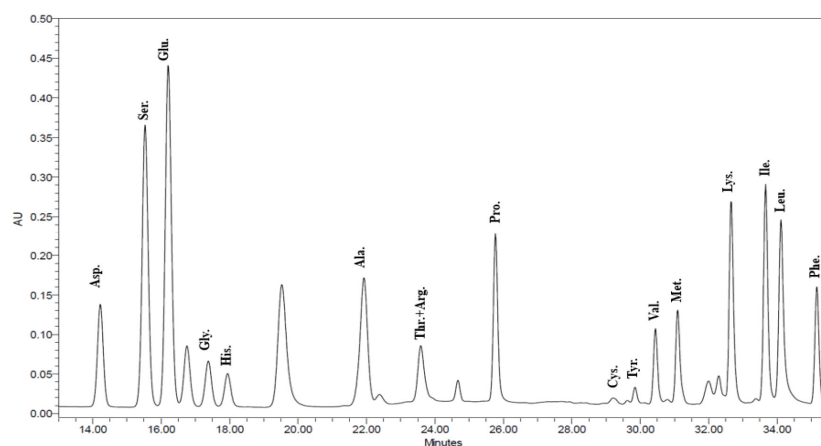


Fig. 12. HPLC chromatogram of amino acids in selected Protamex® hydrolysate fraction.

Table 3. Amino acids concentration in selected fraction

AAs	RT		Area (%)	
	NF3	PF3	NF3	PF3
Asp.	11.284	14.221	2.504	2.649
Ser.	13.688	15.530	3.038	2.892833
Glu.	16.232	16.206	3.602	3.018754
Gly.	17.361	17.378	3.853	3.237067
His.	18.882	17.941	4.190	3.341939
Arg.	10.913	10.963	2.422	2.04212
Thr.	10.913	10.963	2.422	2.04212
Ala.	23.120	23.587	5.131	4.393641
Pro.	25.542	25.769	5.669	4.800091
Cys	28.573	29.207	6.341	5.4405
Tyr.	29.582	29.848	6.565	5.559902
Val.	30.270	30.445	6.718	5.671107
Met.	30.882	31.095	6.854	5.792185
Lys.	32.557	32.658	7.225	6.083331
Ile	33.566	33.664	7.449	6.270723
Leu	33.946	34.113	7.534	6.35436
Phe	34.956	35.161	7.758	6.549575
Unknown AA	48.325	128.095	10.725	23.86075
Total	450.592	536.844	100	

RT, retention time; Area, amount of total amino acids (%); NF3, Neutrase® hydrolysate fraction; PF3, Protamex® hydrolysate fraction.

enzymatic hydrolysates maintained from 30 to 40 min and gradually increased after 50-60 min. This is similar to the previous report (Wang et al., 2013). In this study, the casein contained 95% of protein, and the retention time of hydrolysis was about 10 min.

In this study, fractions separated by molecular weight throughout the Hiprep 16/60 Sephacryl S-100 HR column. In another study, FPLC used either size exclusion or ion exchange chromatography (Kaminarides and Anifantakis, 1993). Chromatographic methods for peptide separation are very diverse, but the purpose of this study was to obtain peptides similar to CPP, so fractions separated using the column separated by molecular weight.

In the case of calcium solubility experiments, no fractions with calcium solubilization higher than CPP found. However, it has a similar level of calcium solubilization, which has confirmed the potential to the CPP. The calcium is solubilized by gastric acid, and most of it is absorbed in the small intestine. If excess phosphate ions present in the small intestine before absorption, calcium reacts to form of calcium phosphate and it is released into the body. Therefore, there is a need to have material capable of preventing such as a precipitation reaction, amino acids and peptides have been reported to have such properties from before (Naito et al., 1972).

Except for the NF6, there were no significance on concentration differences and cell death. In addition, it showed with cell viability of 80% or more.

According to results of the study, as the concentration of fraction samples increased, NO production inhibited. The MTT experiments showed that inhibition of NO and NO production was not caused by cytotoxicity. In previous study, there were results that hydrolyzed proteins significantly inhibited NO production in NO assay experiments comparing non-hydrolyzed protein and hydrolyzed protein (Mukhopadhyaya et al., 2014).

In addition, studies on the inhibitory ability of inflammatory cytokines of casein hydrolysates reported that it have high activities of Alcalase[®] hydrolysates (Mao et al., 2007).

According to results of confirming amino acid sequence of selected fractions throughout the AccQ-Tag system, 17 species of amino acids and several species of unknown amino acids identified. Both fractions had the highest content of phenylalanine. Except for the α_{s1} -casein, there are common sequence feature and it is defined a N-terminal tyrosine residue. Also, it is absolutely essential for activities. Typically, a second aromatic amino acid residue, such as phenylalanine, is also present in the third or fourth position (Clare and Swaisgood, 2000).

Therefore, these protein fractions must be obtained and produced active peptides from them for use as dietary supplements and milk based nutraceuticals. This study identified the potential of new biologically active peptides derived from milk proteins that affect the food and healthcare industry.

Conflicts of Interest

The authors declare no potential conflicts of interest.

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Author Contributions

Conceptualization: Kim CH. Data curation: Cho YA. Formal analysis: Kim DY. Methodology: Yoon HS, Kim CH. Software: Kim DY. Validation: Yoo JS, Yoon HS. Investigation: Cho YA. Writing - original draft: Kim DY, Yoo JS. Writing -

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Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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